International Journal of Disaster Risk Reduction 36 (2019) 101090

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Governance and disaster: Analysis of land use policy with reference to Uttarakhand flood 2013, India

Pratik Dash[a,b], Milap Punia[b,*]

[a] Department of Geography, School of Sciences, Adamas University, Kolkata, 700126, India
[b] Centre for the Study of Regional Development, School of Social Sciences, Jawaharlal Nehru University, New Delhi, 110067, India

ARTICLE INFO

Keywords:
Uttarakhand flood
Policy
Risk governance
Hydrodynamic model
Flood management
Bhagirathi river

ABSTRACT

The flood risks are crucially increasing in developing countries around the globe due to intense development activities and climate change. The extreme casualties and losses wrought by the flood events in June 2013 in the Uttarakhand (India) have raised the governance issues in policy-making and implementation for controlling human activities. Besides extreme rainfall, the unplanned development, weak legal framework and governance issues were claimed as responsible for triggering the disaster. The present study has evaluated the environmental aspects of existing policies related to regulate land use change and development activities when considered in relation to flooding. Analyzing the governance perspective by addressing policy, guidelines and mitigation strategies, this study highlighted the gaps in policies and practice that could be reshaped to reinforce resilience. This study also tried to delineate the high flood level and flood risk area along the Bhagirathi river using hydrological and hydrodynamic models for the event of 2013 that can assist in policy-making process. In summary, the study found that rampant construction at riverside in absence of effective building regulations and hydropower policy in the state has increased the magnitude of the disaster. The lack of multi-institutional co-ordination in formulating and practice of regulatory measures was found as a failure of governance in disaster preparedness and flood management. This study strongly suggests for compliance of local planning authorities and stakeholders with state and national policymakers for establishing collaborative governance. This article may help to bridge the gap between administrators and researcher for formulizing effective flood risk governance.

1. Introduction

Flood, the most recurring natural hazard, is showing an increasing trend of damage worldwide [1,58]. The problems of flooding are becoming acute due to land use change [2,3], urbanization [4], and climate change [5]. The impacts of land use modifications on flooding are amplified by extreme climatic events [6,7] and basin geomorphologic characteristics [8]. Under the changing climatic scenario, anthropogenic activity has a deep impact on mountain ecology and communities, particularly in snow dominant catchments. For instance, the recent deluge in Uttarakhand between 16th and 18th June 2013 is primarily seem to be devastated by torrential rain aided with glacial lake outburst [9], while unplanned development played a crucial role backstage [10].

In the last three decades, significant progress has been made on quantitative assessment of flood risks, flood prediction and warning systems based on space technology and numerical weather modeling [11,12]. Though predictability helps to reduce casualties providing warning for evacuation, flood damages and economic losses could not be reduced. The governance plays an important role to mitigate flood through adopting suitable structural or non-structural measures [13]. The structural measures include construction of flood defences, dam/reservoir; while non-structural measures include regulatory measures like policy, bylaws, land use management, and insurance [14]. For example, construction of flood defence has significantly reduced damages from winter storms [15], while firm implementation of building codes has reduced the impact of the hurricane in parts of coastal Florida [1]. However, since the 2000s there was a paradigmatic shift in flood risk governance from structural measures to non-structural measures by improving mitigation strategy, resilience and policy for controlling human activities through societal transformation [14,59].

Past studies have investigated the role of government policies in hazard mitigation (especially flood) including their governance issues, gaps and limitations in policy implementation [16–18]. For example,

* Corresponding author.
E-mail addresses: pratik.bidyut@gmail.com (P. Dash), punia@mail.jnu.ac.in (M. Punia).

https://doi.org/10.1016/j.ijdrr.2019.101090
Received 13 August 2018; Received in revised form 24 November 2018; Accepted 9 February 2019
Available online 18 February 2019
2212-4209/ © 2019 Published by Elsevier Ltd.

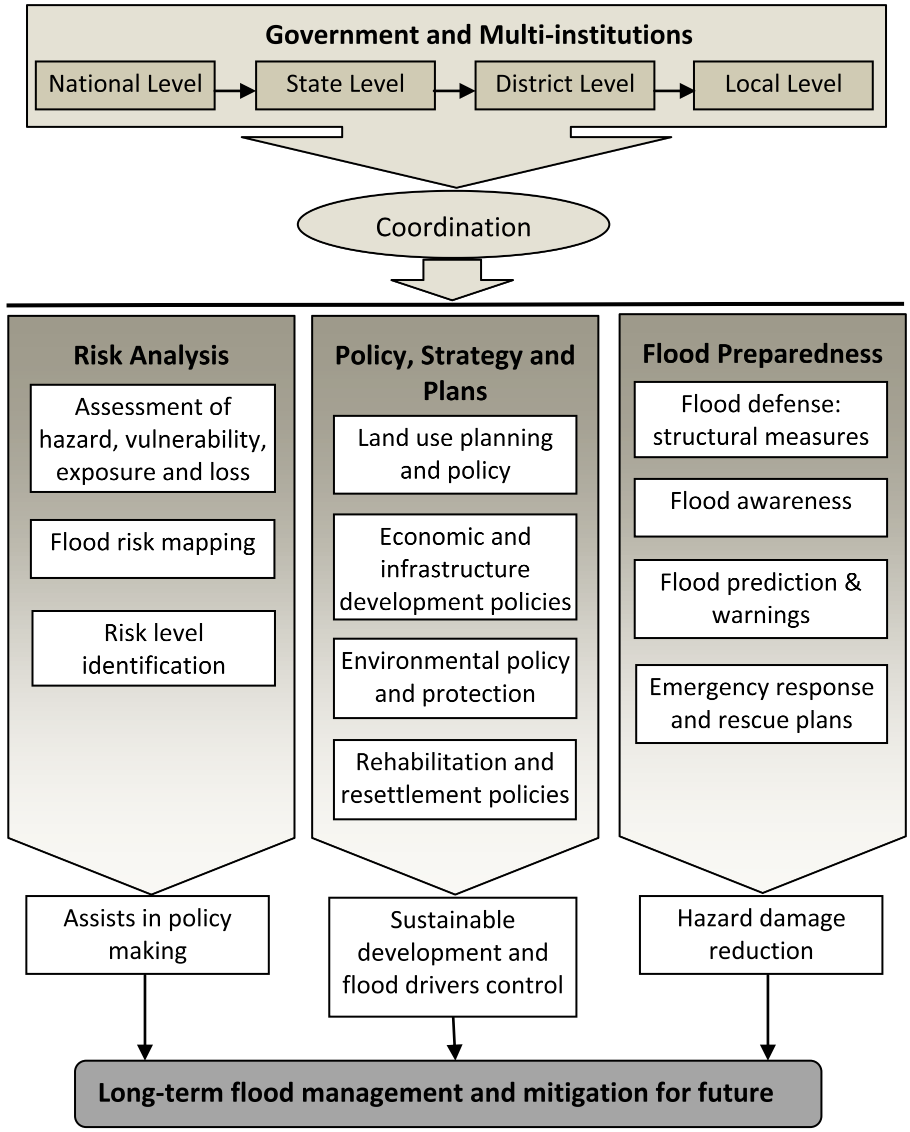

Fig. 1. Conceptual framework of the role of policy and governance in flood management.

Bakibinga-Ibembe et al. [16] critically analyzed environmental laws and policies (including disaster management, land and water act etc.) for addressing periodic flooding and sedimentation in five countries of East Africa. Raju and Becker [19] investigated the role of multi-institutional coordination for disaster recovery after the tsunami in Tamil Nadu, India. Overall, the issues that addressed in past research are: (a) lack of preventative land use policy in disaster mitigation [17,20,21]; (b) decentralization of power and translation of national policy into local flood management [18,22]; (c) failure of governance to implement regulatory measures [20,23]; and (d) information gap and lack of awareness [24,25].

Since, climate change associated with extreme weather events are expected to increase flooding problems in future [26,27], critical analysis of existing policies and governance perspective are crucial for disaster risk reduction. Kumar and Geneletti [21], with a case study from 54 cities in India, have evaluated the performance score of the local plans and policies to understand how awareness, analysis and action components of spatial plans are incorporating climate change issues. The study showed that most of the cities in India are failed to adopt and implement suitable policies to address climate change issues for disaster mitigation. Noticeably, the overall plan performance of Dehradun city (capital of Uttarakhand) is very poor (0.11), whereas Delhi performed the highest score (0.55). With some examples of various mega projects in the Indian context, previous researchers have found the violations of environmental laws and regulations due to gaps in policy drafting and practice due to weak coordination and information gaps among multi-institutions from local actors to national actors [28–30]. Political blame game and judicial inquiry become active to focus the governance issues in controlling regulatory measures after remarkable disasters like, Uttarakhand flood 2013.

In the context of Uttarakhand flood 2013, few studies have estimated hydrological analysis of extreme rainfall event focusing on climate change [60,61], water volume and inundation mapping through hydrodynamic modeling [31], causes and consequences of flood 2013 [32,33]. A few reports have pointed out the weak governance on hydropower regulations and environmental managements [10,34,35]. However, less attention has been paid to study the governance perspective on disaster risk reduction through in-depth analysis on the efficiency and implementation of existing policy and bylaws. With a case study of Bhagirathi river basin, the present article has tried to find out: how development activity triggered flood in Uttarakhand, and how good governance can control development activities to minimize flood risks. To address these questions, the specific objectives targeted in this study are: (i) delineation of maximum flood extend along the stretch of

Bhagirathi river to identify flood risk areas; (ii) role of anthropogenic activities in triggering the flood, and (iii) critical discussion on governance issue of existing policy and its gap to address sustainable development and flood control. The present study has tried to bridge between the technical science (hydrodynamic modeling) and risk governance to enhance our understanding on building flood resilience.

2. Role of policy and governance in flood mitigation

Considering the carrying capacity of land, sustainable land development is very beneficial for flood risk management and economic development allowing necessary land utilization to continue [36]. On the contrary, unplanned utilization of land often causes environmental problems that affect economic stability impacted by disaster. Hence, control of land utilization through the implementation of land use policy is the most promising long-term solution for mitigating hazards and environmental degradation [17]. In general, land use and development policies are adopted at various levels of Government to foster: (a) land allocation for different usage considering land capability, economic and environmental efficiency; (b) reclamation of land productivity and arrest of further degradation; and (c) environmental management for minimizing hazards [37].

Land use policy and planning can assist in flood management by reducing the vulnerability and exposure of the community to the disaster, as conceptualized in Fig. 1. The policies include building regulations, land utilization act, environmental protection act, disaster management act, water policy etc. that control pattern and mode of human activities emphasizing conservation of environment and ecology, disaster protection and control measures. For example, building regulation mandates for minimum distance of houses from river, building structure, floor height, etc. to minimize flood damage and water logging problems [38]. Environmental acts and policies are implemented to protect sensitive zones by limiting development activities that triggers landslide, peak runoff, soil erosion etc. Land acts, on the other hand, control land transformation by restricting the conversion of wetland and water body to other land use types [16]. However, policy drafting without proper practice is not sufficient for flood management. Policy dimensions and good governance (both political and bureaucratic) plays a vital role in flood management [39]. Since, the impact of flood hazard is maximally felt at local scale, decentralization of power to local government for incorporating local level plans and monitoring, and supporting technical assistance is the best way to reduce flood vulnerability and environmental degradation.

3. Study area

Bhagirathi river, the source tributary of river Ganga, is originated from the Gomukh in the Gangotri glacier and meets Alaknanda river at Devprayag. Extending over 217 km long stretch in Garhwal Himalayas, the river covers 8847 km^2 area in Uttarkashi and Tehri Garhwal district in Uttarakhand (Fig. 2). The elevation of the basin ranges from 460 m to 6900 m with an average of 3000 m. The major soil types of the basin are loamy, loamy-skeletal, sandy loam, and clay. Meteorologically, the climate varies from tropical, sub-tropical, to sub-arctic types in the region. The mean annual precipitation ranges between 1500 and 2000 mm that varies with altitude. The entire basin receives maximum rainfall (75%) by the southwest monsoon during June–September. The areas in the upper catchment of the river receive snowfall.

Vegetation is the dominant land use land cover type that covers about 45% of the basin area. The other types are snow cover, barren land, cropland and built-up area (Fig. 3a). A large forested area in Uttarkashi district has been cleared for hydropower projects, roads and transmission lines [40]. Rampant development activities are disturbing the natural ecosystem in this mountainous environment. For example, the construction of a series of dams on the Bhagirathi River for hydropower projects (Fig. 3b) has interrupted river flow in a stretch of about 110 km between Maneri in Uttarkashi district and Koteshwar in Tehri Garhwal district [34]. The population in the study basin has significantly increased from 2001 to 2011, especially in Uttarkashi district. The total population of Uttarkashi district increased from 295,013 in 2001 to 330,086 in 2011 with a decadal growth of 11.89%, while in Tehri Garhwal district it increased by only 1.02% in the same period [41]. About 90% of the total population is living in rural areas. The study area is very attractive to tourist for its scenic beauty and religious significance.

4. Methodology

4.1. Materials

The policy framing for risk governance could be given a better shape with scientific analysis of flood risk through numerical modeling [42]. Therefore the present study used hydrodynamic model to calculate the maximum extension of flood towards banks along the main channel of the Bhagirathi river. The input for modeling requires topographic information, land and soil characteristics, meteorological informations etc. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) of 1 arc-second (~30 m) spatial resolution was used for the input of topographical information. The land use map of 2010 was prepared from Landsat TM image using supervised classification technique (Fig. 3a). A soil map (1:125,000) including soil types and properties was collected from National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) of India. The meteorological input comprising daily rainfall, temperature (max and min), wind speed, relative humidity, and solar radiation were collected from the Texas A&M University spatial sciences web-portal (http://globalweather.tamu.edu/) for 9 locations (Fig. 2) in/around study basin for the period of 2008–2013. The study has used 8-day composite MODIS evapotranspiration data product (MOD16A2) for the period of 2009–2013 collected from USGS web portal.

4.2. Estimation of high flood level and risk area

In this study, hydrodynamic modeling, coupled with hydrological model, is used to identify the flood risk area and high flood level (HFL). These models try to formulate natural processes through equations based on certain input criteria and parameters. In simple term, hydrological model compute the amount of runoff for a given amount of rainfall under a certain land and topographic characteristic, while hydrodynamic model simulates flood water depth and extension for a given peak discharge. The popularly applied Soil and Water Assessment Tool (SWAT) hydrological model [43] is used in the present study to compute the volume of peak discharge during 16th–18th June 2013 in Bhagirathi basin. The spatial variability in hydrological processes at basin scale is considered by dividing the catchment into numerous subbasins and hydrological response units (HRUs). Within the model interface, this study used Pennman–Monteith method for calculating potential evapotranspiration, and modified SCS (Soil Conservation Service) curve number method for surface runoff calculation. The simulation setup pertaining to land use of 2010 was run for the period of 2008–2013 with initial one year as warm-up period. To adjust model parameters for obtaining a realistic result, the model was calibrated (2009–2011) and validated (2012–2013) with MODIS actual evapotranpiration, as observed discharge data could not be acquired. It is noteworthy to mention that calibration of SWAT model with evapotranspiration data instead of discharge data is an established method for ungauged basin [44].

The simulation of flood extent was performed using Hydrologic Engineering Center's River Analysis System (HEC-RAS) hydrodynamic model developed by U.S. Army Corps of Engineers (USACE). HEC-RAS is an open source one-dimensional (1-D) hydraulic model that extensively used to compute water extent for a given peak flow (unsteady

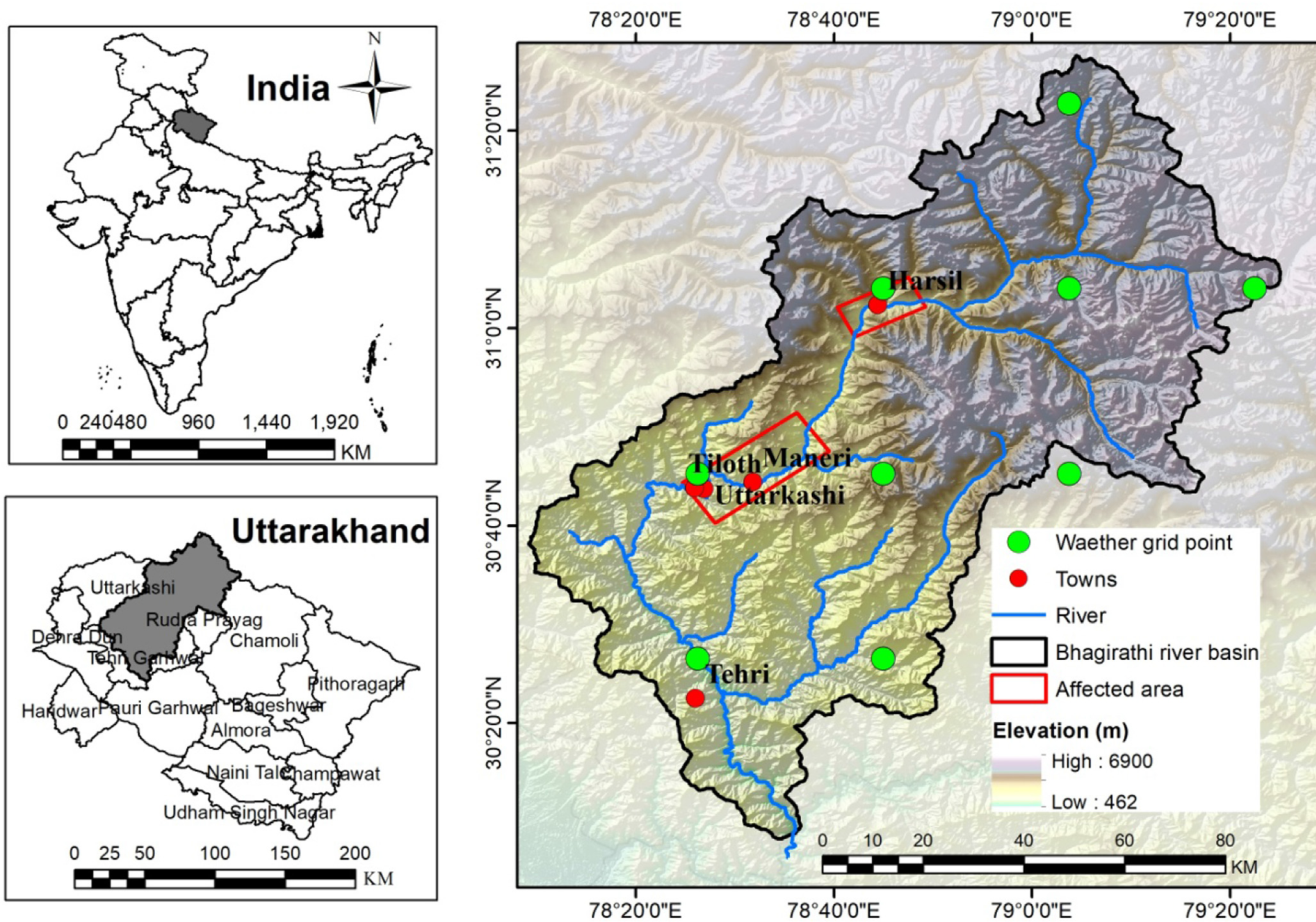

Fig. 2. Location map of the Bhagirathi river basin. Area demarcated by red boxes were affected severely by the flood event of 2013. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

flow) condition or sub-daily flow conditions [4,31,45]. The minimum input parameters required for the model are channel and basin geometry, surface roughness characteristics and discharge amount. The geometric input that includes stream centerline, bank line, flow path centerline, cross-sectional cutline, storage area etc. were prepared in HEC-GeoRAS (via ArcGIS extension) for HEC-RAS model setup. A triangulated irregular network (TIN) was created from the DEM to extract geometric information, while Google Earth image was used as a basemap for the digitization of geometric layer. The main channel of Bhagirathi river was considered for hydraulic modeling as the major damage from deluge (June 2013) was noticed in two location along the mainstream (boxes in red color showed in Fig. 2). A lookup table of manning's *n* value (roughness coefficients) was prepared using land use map and extracted for each cross section. The geometric data layer prepared in HEC–GeoRAS was finally exported into HEC-RAS model. The flood inundation simulation was modeled in HEC–RAS using unsteady flow conditions. The simulated streamflow data for 16th–18th June was imported from SWAT model to HEC–RAS model for estimating the extension of inundated area. Finally, HEC–RAS result was post-processed in HEC- GeoRAS for flood inundation mapping.

4.3. Policy analysis

The existing policies, bylaws, guidelines and court orders related to building constructions, tourism infrastructure development, forest and environment, river management, and other development activities are qualitatively analyzed considering the role of anthropogenic factor on the flood.

5. Results and discussions

5.1. Flood inundation mapping

Coupling hydrological model (SWAT) and hydraulic model (HEC–RAS) maximum flood extent was mapped for the peak runoff occurred during 16th–18th June 2013 that brought severe flood in the area. Initially SWAT model was calibrated manually by adjusting model parameters for a close match of simulated actual evapotranspiration (ET_a) compared with MODIS ET_a. The optimum calibration results showed suitable statistical performance of the model with coefficient of determination (R^2) 0.78, and Nash-Sutcliffe efficiency (E_{NS}) 0.66. However, simulated hydrological components checked with SWAT Check program [46] to resolve ambiguity in the separation of streamflow components. The estimated daily peak discharge at the basin outlet has varied as 430–2700 m^3/s from 16th–18th June 2013. This peak discharge induced by catastrophic rainfall in between 16th–18th June in Bhagirathi, as well as Alaknanda river basin, has led devastating flood in Uttarakhand. According to the Climate Diagnostics Bulletin of India [47], the state received exceed of 340 mm of rainfall on 17th June, which is 375% more than the normal daily rainfall (65.9 mm). During 14th–19th June 2013, about 800% more than the average rainfall is received in Uttarakhand, in which 381 mm, 359 mm, and 326 mm is received at Tehri, Uttarkasi, and Tharali [48].

An unsteady flow was simulated in HEC–RAS interface with predefined boundary conditions and peak discharge. The extent of water level modeled on daily basis for the flood event of June 2013. The maximum extent of inundation along the flow path of mainstream during this deluge is presented in Fig. 4. Since the calibration of

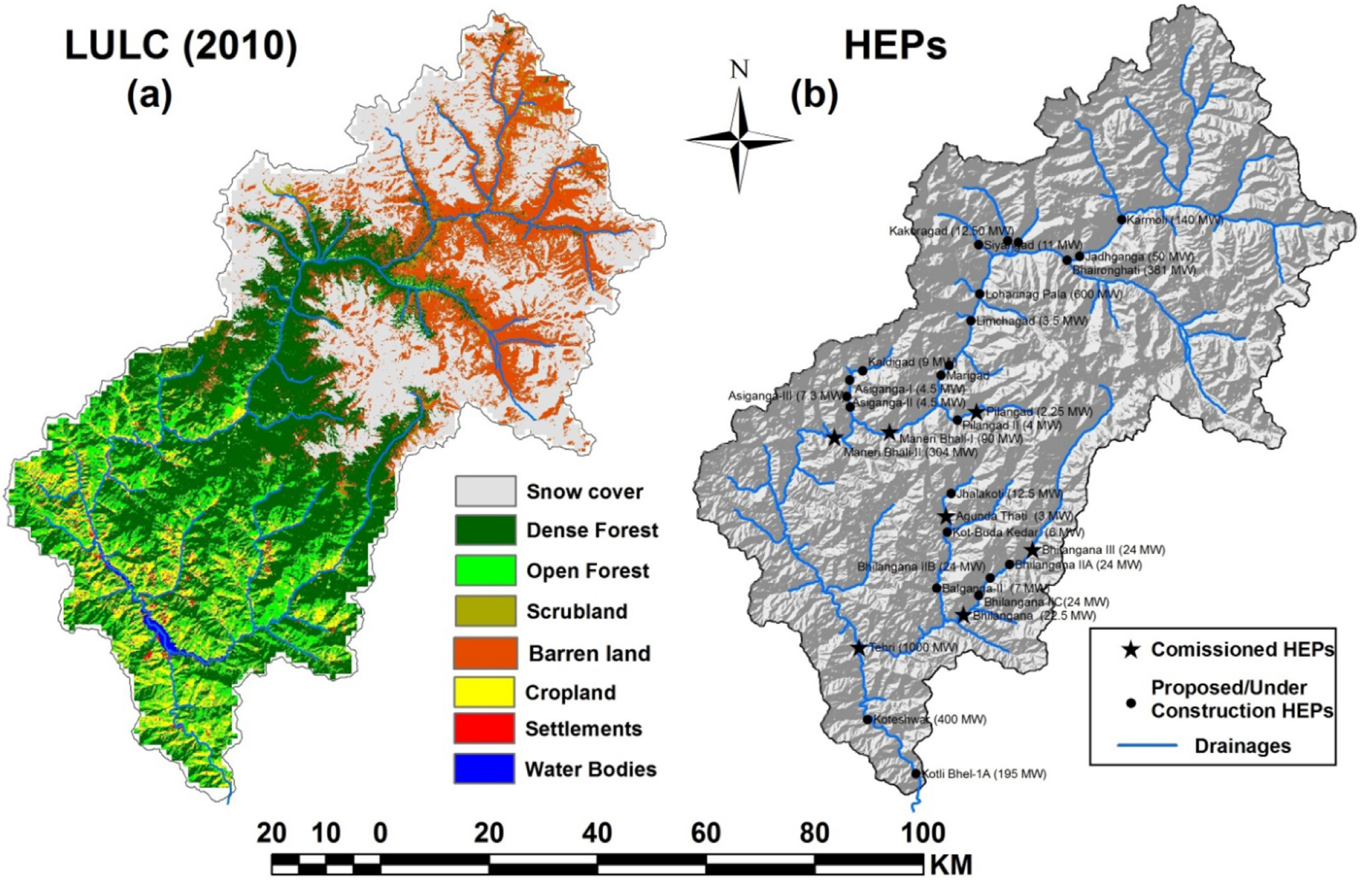

Fig. 3. (a) Land use land cover (LULC) map of 2010, and (b) location of hydroelectric projects (HEPs) in the Bhagirathi river basin.

HEC–RAS model was limited for the study, the model output was verified with the water extent profile drawn from the signature of flood damage captured by the Google Earth image in post-flood period. The flood inundation map was overlaid with settlement map to identify the villages prone to flood risk (Fig. 4). It is noteworthy that uncertainty in hydrological and hydrodynamic modeling arose from data paucity and model structures are ignored, as the study primarily aimed to focus on policy and governance issues. The reported villages that severely affected by the flood in June 2013 are Dharali, Tiloth, Harsil, Joshiyara, Bhatwari, Kharadi, Pilang, Jadau, Didsari, Maneri, Mandon, Uttarkashi ward no. 1, 2 and 5 [35,49]. Most of these villages and town are found within/or near to the simulated flood water level in these two locations as showed in Fig. 2.

5.2. Role of development activity on flood

In this section, the mode of human activities that seemed to be influential for the flood in Uttarakhand are discussed, which is essential to understand prior analyzing the role of governance in policy making and practice for disaster mitigation. The widespread development activities for the construction of buildings, transportation, hydropower and other infrastructure along the river valley are became a concern in light of flood 2013. After being a new state in 2001, a significant initiations and plans have been made by the state government to boost the economy and tourism sector. The total tourist influx has been increased about two times in 2013 as compared to 2001 (Ministry of Tourism, Uttarakhand). A large number of hotels, guest house, and other infrastructure were constructed to accommodate tourists [32]. Besides, the settlements surprisingly spread out along the banks of Bhagirathi and Alaknanda river with the increase of economic opportunities from tourism, hydropower projects, mining etc [32]. Noticeably, as the scope of horizontal expansion is limited, vertical expansion was promoted through the construction of multi-storied buildings even ignoring unstable eco-sensitive land including dry river bed and fluvial terrace close to water flow [35]. Massive construction for tourism and residence in the eco-sensitive region has been expected as crucial to intensify the calamity. This finding is seemed to be true as five districts in the state (including Uttarkashi) where the development of tourism infrastructure has been extensively promoted were worst affected by 2013 flood [49].

By virtue of suitable physiographic location, Uttarakhand stands second highest in potential hydropower in the country. To increase the revenue and power generation, the state government has allowed constructing a huge number of hydroelectric projects (HEPs) of various sizes. Noticeably in the course of Bhagirathi and Alaknanda more than 200 HEPs are either under construction or sanctioned and 42 HEPs are operational [32]. Besides the impact on river dynamics, water quality and ecosystems, HEPs have a significant influence on flood vulnerability. During the extreme rainfall event, the torrential flow while obstructed by lock gate force to collapse buildings and other structure along the banks through toe erosion. For example, Assiganga I and II HEPs (4.5 MW each), and Maneri Bhali I and II HEPs (90 & 304 MW) on Bhagirathi river, Vishnuprayag HEP (400 MW) on Alaknanda River and Dhouliganga HEP (280 MW) on Dhouli ganga caused serious damage in the downstream areas [50]. In addition, sudden opening of lock gate without prior information is also responsible for devastation in the downstream area. For example, Srinagar HEP (330 MW) closed lock-gate in the evening of 16th June 2013, but suddenly opened in the early morning of 17th June 2013, that flooded and collapsed hundreds of buildings in Srinagar town at the downstream of Alaknanda river.

To facilitate tourist, HEPs, mining and other activities a large numbers of roads constructed in Uttarakhand under state and national

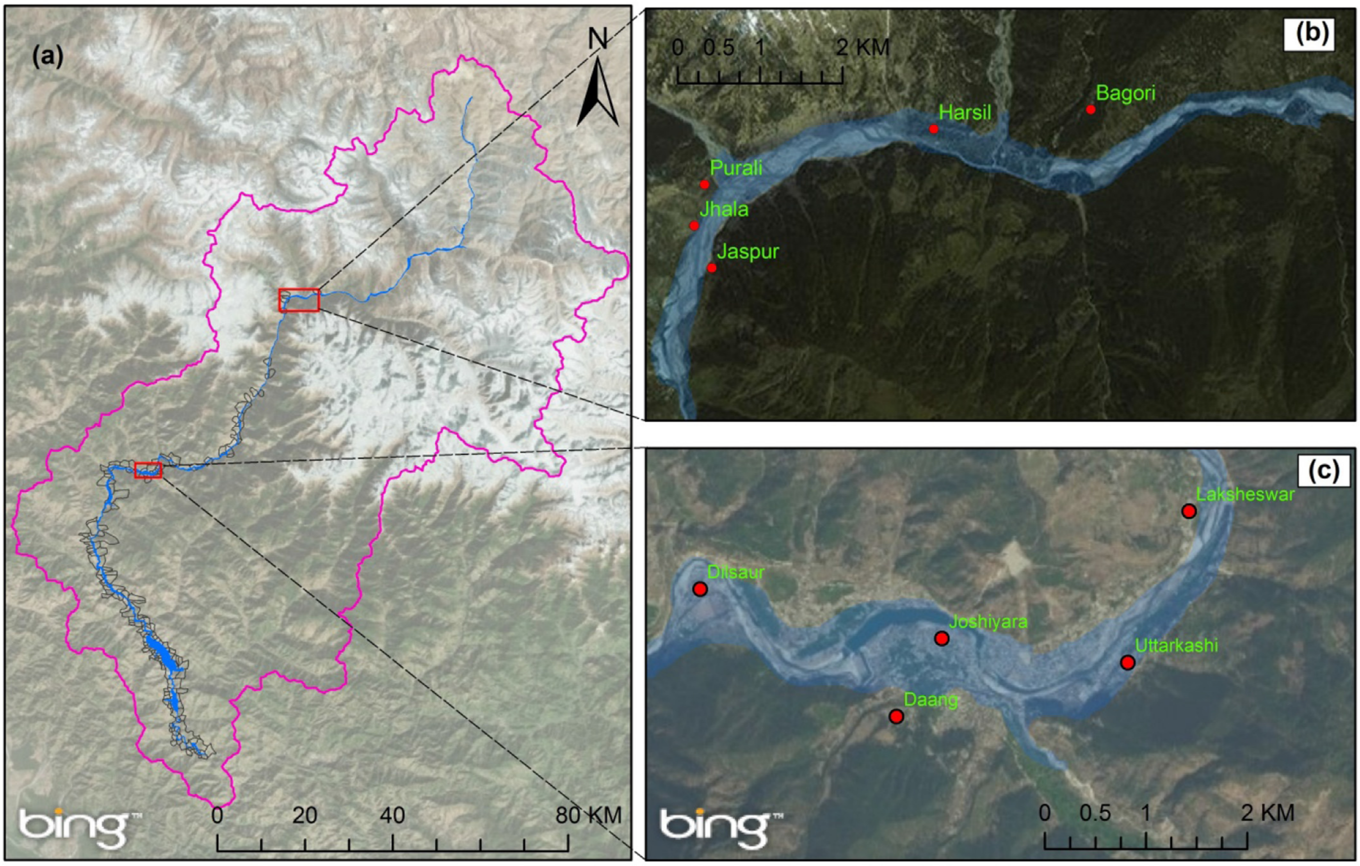

Fig. 4. Simulated maximum water extend during flood 16th −18th June in (a) Bhagirathi basin river basin along the mainstream; (b) area around Harsil Village, and (c) Uttarkashi town. Flood inundated area showed in blue shade over base layer of Bing Map. Villages more prone to flood risk are shown in black polygon in figure (a). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

schemes. For example, about 4500 km of road has been constructed in Uttarakhand under the '*Pradhan Mantri Gram Sadak Yojana'* (Prime Minister's Rural Roads Scheme) scheme since 2010 [51]. Engineering works for quarrying, tunneling and other works for road construction, and heavy traffic flow have increased the instability of mountain slopes that triggered landslides. Moreover, dumping of debris and muck generated from construction and maintenance of roads, HEPs, mining, and other constructions often blocks channel flow that became destructive during the deluge.

Deforestation is another crucial factor that directly or indirectly triggering flood risk. A total of 38,814 ha of forest land in the state have been converted to non-forest use since 2001 to till 31st August 2014 [52]. Construction of HEPs, roads, settlement, other infrastructure, and land conversion for cropland forest felling has been practiced at a large-scale in Uttarakhand. Deforestation contributes in deluge by triggering landslide, soil erosion and increasing overland flow by reducing infiltration capacity. For instance, the maximum deforestation in Uttarakhand was taken place in four districts viz. Chamoli, Pithoragarh, Rudraprayag and Uttarkashi that were worst affected by flood in 2013 [40].

5.3. Analysis of regulatory measures for disaster risk reduction

In this section, the existing regulatory measures pertain to land development activities in connection with flood vulnerability and environment protection have been critically analyzed accounting the mode of implementation and gaps in the policies. The existing policies, regulations, guidelines and court orders to restrain human activities are summarized in Table 1.

Department of Housing, Government of Uttarakhand had adopted Building Construction and Development bylaws in 2011 (amended in 2015). According to this bylaw, the minimum distance of any building from water flow is 30 m (section 4.4. iii) (Table 1). This bylaw seems scientifically irrational, and keeps vague without defining the position of the river flow in terms of middle of the flow, edge of flow during high flood or low flood. From the flood inundation mapping for the event of 16th–18th June 2013 in Bhagirathi river, the present study found that the average extent of water on both sides from the stream centerline is 185 m. This analysis justifies the order of Uttarakhand high court on 26/08/2013 for banning all kind of construction activity within 200 m of all rivers in Uttarakhand (Table 1). While in Himachal Pradesh (a sister state of Uttarakhand), the Town and Country Planning Department[1] had adopted a policy in 2011 for Mandi Planning Area exerting: (a) zone of 'no construction' in the land below the High Flood Level (HFL) treating as river land, (b) beyond the HFL, a "Green Zone" in a belt of 25 m buffer along the banks of Beas river strictly for afforestation, soil conservation measures, park etc. without allowing any construction. Another major drawback of the existing policy is in the approach of generalization of laws. The policy included a separate provision of few building codes (like floor area ratio, building heights and floor numbers etc.) for only two topographic regions i.e. plains and hilly area. Overall, the policy hardly mandated a separate provision to emphasize local geo-environmental factors i.e. topographical, geotechnical, ecological and climatic factors that vary from place to place.

[1] Town and Country Planning Department, Himachal Pradesh, 2011, Official Gazette of Himachal Pradesh, Development Plan for Mandi Planning Area, Chapter-19.

Table 1
Summary of existing policies and guidelines related to land use and development activities and environmental protection.

Category	Level of authority	Policy name	Year/Date	Regulations
Residential building construction	Housing Section-2, Government of Uttarakhand	Building construction and development bylaws[a]	2011(amendment 2015)	● Minimum distance from water flow: ~30 m (river), ~5 m (sewer), ~10 m (underground water flow) ● No construction at landslide prone area ● No construction at any side where local slope is more than 30% ● Maximum 12 m height and 3rd floor for single plot (hilly region)
	Ministry of Home Affairs, Govt. of India	Building construction and development bylaws for rural area[b]	2008	● Permission needed from Gram Panchayat for any kind of building construction ● Plot size should be less than 500 sq. meter ● Maximum height of buildings 10 m and 3rd storey. In exceptional cases, the height may be relaxed by Zila Parishad.
	Uttarakhand high court	High court order	26/08/2013	● All construction activity within 200 m of all rivers in Uttarakhand state is banned.[c]
Infrastructure development and mining	River Valley Development Authority, Govt. of Uttarakhand	Uttaranchal River Valley (Development and Management) Bill[d]	2005	● No development of land shall be undertaken or carried out or continued in Bhagirathi river valley area by any person or body including a department of Government or any undertaking in public or private sector, unless permission for such development has been obtained in writing from the River Valley Development Authority (Section 11(3)). ● No Construction or Development shall be permitted in the catchment area of River Valley or near the Reservoir/Dam in contravention of the Master Plan or Sectoral Development Plan. (Except for public purpose like construction of the Bridges, Preventing floods, Control of soil erosion, Construction of HEP etc, or any work incidental thereto) (Section 21(2)). ● No commercial Mining activity shall be carried out in the catchment area of River Valley without the permission of the River Valley Development Authority
	Uttarakhand high court	High court order	16/12/2014	● No mining can be done in any river flowing within the boundaries of a reserve forest[e]
Construction for tourism	Uttarakhand Tourism Development Board	Infrastructure Development Guidelines[f]	2015	● Site to be at a safe distance/buffer of 500 m from river banks ● Not be sited above 2000 m elevation ● Proper EIA required for resorts or any large-sized tourism infrastructure ● Geo-technical studies and slope stabilization measures mandatory for tourism infrastructure development in Himalayan region. ● All tourism properties shall take clearance from Uttarakhand Environment Protection and Pollution Control Board (UEPPCB), and all large tourism properties i.e. above 20,000 sq. m area shall take clearance from State Level Environment Impact Assessment Authority (SEIAA)
Environment protection and hydroelectric project (HEP)	Govt. of Uttarakhand	Hydro Power Policies and Guidelines	2008	● Mini/micro HEP (< 2 MW) is reserved for Panchayat Raj Institutions (PRIs); small HEP (2–25 MW) can be handled by non-GoU (Government of Uttaranchal) agency for a period of forty years; HEP of 25–100 MW can only be handled by the GoU bidders for a period of forty five years; large HEP (> 100 MW) installed by private sector for a period of forty five years
	The Ministry of Environment & Forests (MoEF), Govt. of India	1. Forest (Conservation) Act, 1980 and the Forest (Conservation) Rules, 2003 2. Environmental Protection Act (1986) 3. Eco Sensitive Zone (2012)		● Private project developers and state agencies (like UJVNL) have to transfer an area of non-forest land equivalent to the forest land diverted for the project to the Forest Depart for Compensatory Afforestation. ● Catchment Area Treatment (CAT) mandatory for HEPs (> 10 MW) ● 100 Kilometre stretch of Bhagirathi river from Gaumukh) to Uttarkashi town declared as eco sensitive zone to control development activity.
	Govt. of India	The Dam Safety Bill (Bill No. 108 of 2010)	2010	● Every owner of specified dam shall establish a hydro-meteorological station in the vicinity of at each such dam. [Section 33(1)] ● Every owner of a specified dam, in the case of specified dam being of 30 m height or above or specified dam being falling in the seismic zone III or above, shall establish a seismological station in the vicinity of each such dam. [Section 34(1)] ● Every owner of the specified dam carry out risk assessment studies at an interval of twenty years or at such interval as may be specified by the regulations made by the Central Dam Safety Organization. [Section 35(2)]

(*continued on next page*)

Table 1 (*continued*)

Category	Level of authority	Policy name	Year/Date	Regulations
				● Set out the procedures to be followed for the protection of persons and property upstream or downstream of the dam in the event of an actual or imminent dam failure or to mitigate the effects of the disaster. [Section 35(3)]

[a] *Amendment to Building Construction and Development Byelaws/Regulations–2011, (Text in Hindi) issued by Housing Section-2, Government of Uttarakhand vide No. 739/V-2013-24(H)/2009 dated 28 May 2013.*

[b] *Model Guidelines for Development & Building Construction including safety provisions for Natural Hazards in Rural Areas (India), 2008. UNDP Disaster Risk Management Program, Ministry of Home Affairs, Govt. of India, New Delhi.*

[c] *High Court of Uttarakhand at Nainital, 26 August 2013, Writ Petition (PIL) No. 25/2013; Sanjay Vyas vs State Of Uttarakhand & Others.*

[d] *Uttaranchal River Valley (Development And Management) Bill, 2005, No 416/Vidhayee & Sansadiya Karya, Government of Uttarakhand.*

[e] *High Court of Uttarakhand at Nainital, 14 November 2014, Writ Petition (PIL) No.160/2014, Ranjeet Singh Gill vs State Of Uttarakhand & Others.*

[f] *Uttarakhand Tourism Development Board, Infrastructure Development Guidelines: Developing new infrastructure under tourism sector, including any rehabilitated and reconstructed tourism infrastructure (UTDB-IDG-01), March 2015.*

The Government of Uttarakhand (GoU) though initiated various developments in tourism sector since 2001, did not adopt any strict policy for development of tourism infrastructure. The GoU has taken a lesson from the disaster of 2013 and prepared only a guideline for construction of buildings for tourism in 2015 rather than a legitimated policy (guideline summery given in Table 1). The GoU targeted to increase the number of tourists through providing more accommodation, overlooking the formulation of concrete policy for tourism development. As a result, mushrooming of guesthouse and hotels invading riverfront in support with local authority and state government has increased the flood risk. The GoU and local administration have failed to control land use and development activities that often exceeded the carrying capacity of sensitive zones [53]. The new guideline has adopted restrictive approach that incorporated various important aspects like, no construction zone within a buffer of 500 m from river, special clearance from UEPPCB and SEIAA, mandatory environmental impact assessment (EIA) for large projects etc. (Table 1). However, there is a lack in encouragement for home stay facilities, eco-friendly hut and tent, temporary construction etc. that are more suitable for this fragile mountainous ecosystem.

The GoU had adopted the Uttaranchal River Valley (Development and Management) Act in 2005 to regulate any development activities in Bhagirathi river basin for keeping the river in a pristine state. The act clearly stated that no construction and mining activities in the basin area shall be permitted without the permission of River Valley Development Authority (Table 1). But governance failure in policy practice is quite visible to regulate illegal and unplanned activities. Even, the government and local authorities promoted illegal activities by legalizing it. For example, GoU allotted land from dry river bed to public and private sector by transforming river as land in revenue record; even the government also permitted for constructions.[2] The high court of Uttarakhand, on July 2013, directed GoU to cancel all allotments and reinstate the river to its original condition by removing all constructions. The high court stated that:

> “The State Government cannot even, by law, assume upon itself the power to convert the land of a river into dwelling place of people. […. .] no river belongs to a particular State.”[2]

Interestingly, the role of governance in developed countries is quite different from India in flood risk reduction. The government of Germany and England had prepared a special act “room for rivers” and “making space for water”, respectively, in 1990s focusing land use regulation as a central part of flood management approach [14]. A better governance must ensure river front protection by adopting a strict policy to control development activities in flood plain (or river valley) area.

The GoU has also showed lack of willingness to control mining activities and muck disposal in river valley side. The Expert body, constituted as per the direction of Hon'ble Supreme Court vide judgment dated 13.08.2013 found that improper management and inadequate maintenance of muck dumping sites along Bhagirathi river basin [35]. Since, after the report of the Comptroller and Auditor General of India (CAG) in2010[3] in violation of MoEF rule for muck disposal, the state government didn't take fruitful step. For example, at HEP in Maneri Bhali-II only 10% of generated muck used for construction works, while the MoEF recommended maximum possible extent of 50% should be used for construction purpose in the same project. The National Green Tribunal, in April 2014, ordered the state government to take appropriate steps for muck disposal by ensuring the prevention of any

[2] High Court of Uttarakhand at Nainital, 4 July 2013, Writ Petition (PIL) No. 233/2008, Smt. Beena Bahuguna vs State Of Uttarakhand and Others.

[3] Comptroller and Auditor General (2010) “Performance Audit Report of Hydropower Development through Private Sector Participation, Uttarakhand for the Year 2008-2009”, Report of the Auditor General, Uttarakhand.

damage to properties, especially by throwing muck into the river bed.[4] Noticeably, the state government did not prepare any policy for muck disposal and management. The government requires preparing an intensive strategic and management plans for all kinds of construction, muck disposal, mining on river bed etc. to reduce flood vulnerability by protecting the environment.

The GoU had taken a very invest-friendly and attractive policy to increase the number of HEPs in the state. The hydropower policy of the state goverment (2008) mainly focused on the clause of ownership and tenure of the project (Table 1), rather than paying attention to environment protection, dam safety strategy and hazard preparedness. The policy never mandated for environmental impact assessment (EIA), even for establishing a large HEP. Throughout the state, numerous HEPs were commissioned, under construction and planned for installation ignoring river ecology, channel fragmentation, minimum environmental flow etc. [35]. Therefore, the Supreme Court of India ordered in August 2013 to stop the proposed 24 HEPs in Alaknanda and Bhagirathi river basin and recommended for EIA of existing HEPs in the state. Interestingly, the state government rejected the findings of the report doubting on the reliability of the report as the expert committee did not performed scientific analysis [54]. However, there are no proper guidelines recommended by the state government, as well as, by the central government for lock gate operation during high flow or deluge. The Dam Safety Bill of the Government of India (2010) was not properly followed by the state still now. The Expert Body [35] reported that many HEPs didn't have their own meteorological station in the project site. Catchment Area Treatment (CAT) plan was not followed properly to check soil erosion. In addition, this bill (Section 35(2)) recommends an interval of 20 years for periodical risk assessment which is expected as too long for risk assessment as climatic conditions are drastically changing.

The GoU had prepared a draft on Uttaranchal Disaster Mitigation, Management and Prevention Act in 2005 to foster an integrated and coordinated system of disaster management for prevention and mitigation of disaster incorporating local authorities, stakeholders, and communities. The Uttaranchal state disaster management authority (USDMA), headed by the chief minister, solely responsible for planning, coordinating and monitoring for disaster management and post-disaster reconstruction, rehabilitation, evaluation, and assessment.[5] This act is itself well documented that incorporated power decentralization to the local authority pertaining to disaster mitigation plan and strategies, effective measures and action for disaster reduction. According to this Act, SDMA is powered to inspect the quality of construction of any building or structure in any local area in the state; and demolish the unsafe structures which may endanger the public. However, the state government had failed to implement of this act that raised the question on accountability of the government.

5.4. Major gaps in policy and governance issues

Analyzing the policies of the state and central governments pertaining to land use regulation and environment protection considering the impact on flood, some major gaps have been identified that addressed in this section.

1) *Risk analysis and pilot study*: The first priority in risk governance should be given to risk mapping, asset mapping, and designing special plan for high risk areas. The GoU did not prepared detailed risk map though the state is highly prone to flood and landslide. The risk analysis may allow different restrictiveness that varies with land use categories based on the vulnerability. In Germany, different restrictiveness on land use modifications has been incorporated in flood management plan based on the return period of floods [14]. Pilot study of a new approach for flood management (structural or no-structural measures) is very effective for policy drafting and implementations. Before adopting a new catchment flood management plans in England and Wales, a pilot study has been conducted for various catchments incorporating hydrodynamic modeling and other scientific analysis to identify the effectiveness and lacuna in the proposed plan [42]. In Netherland, the state defence agencies constantly monitor and evaluate the safety level of structural measures at every five years [55]. Moreover, large scale risk mapping also helps to identify local criteria that can be portrayed in policy making process.
2) *Issues in policy drafting and implementation*: The major gaps found in existing policies are related to rigidity and approach of the policies, willingness to legitimate policies, conflict in division of authorization and power, importance of local authorities in policy making process. Firstly, there is a lack in adopting restrictive approach, especially for disaster prone area. A study conducted by Krieger [14] showed that Germany got effective result in flood hazard mitigation as compared to England by adopting restrictive approach in land use policy. Secondly, the GoU has prepared guidelines for developing tourism infrastructure, hydropower projects etc. rather than a strong legitimate policy. On the other hand, absence of mining policies, forest protection bill, protection for natural resources, and flood management bill creates ambiguity in land use policy. Thirdly, the division of power to local level for policy implementation and supervision is clearly unstated in most of the cases. Interestingly, Uttaranchal Disaster Mitigation, Management and Prevention Act (2005) has exceptionally incorporated the clear division of power, role of local authority etc., but did not adopted as legitimate policy till now.
3) *Lack of awareness*: Direct participation of community in land use management and local level planning is very effective for disaster risk reduction. In USA and Germany, the community has important role in decision making process to control land use modification. Considering a central part of risk mitigation strategy, the government of USA took various initiatives to increase awareness of flood threat, flood plain management [55]. Analyzing the various policies, the present study found a lack in governance to incorporate community awareness programme in the policy framework. The experience from the field survey reflects that the local communities are hardly familiar with the policies and risk awareness.
4) *Lack in multi-institutional coordination*: Strong coordination among institutes at horizontal and vertical levels for policy making and implementation is essential for effective risk governance. The lack of co-ordination among actors is reflected in the policies. For example, building construction and development bylaws (2011) of GoU did not incorporated the role of River Valley Development Authority who is the sole authority to control development activities in Bhagirathi river valley region (Table 1). The conflict of interest and power division among state actors create problems in policy implementation and regulation. In addition, lack in translation of national policy to local level percolated through the planning authorities and the state institutions is important to highlight local problem in policy making process that was not reflected in existing policy of building bylaws, tourism infrastructure development guidelines, state hydropower policy etc.
5) *Lack in resettlement and rehabilitation policy*: A firm resettlement and rehabilitation policy becomes a backbone to the vulnerable communities for restoring socioeconomic stability after a disaster. Unfortunately, the GoU didn't adopt any resettlement and rehabilitation policy till date. The state government only formulated Uttarakhand Reconstruction and Rehabilitation Authority fortnight after the disaster 2013 [32]. After the deluge 2013, most of the local

[4] National Green Tribunal, 24th April 2014, OA No. 322/2013, Vimal Bhai v Jaypee Associates & Others.

[5] The Uttaranchal Disaster Mitigation, Management and Prevention Act, 2005, Act 29/2005, Government of Uttarakhand.

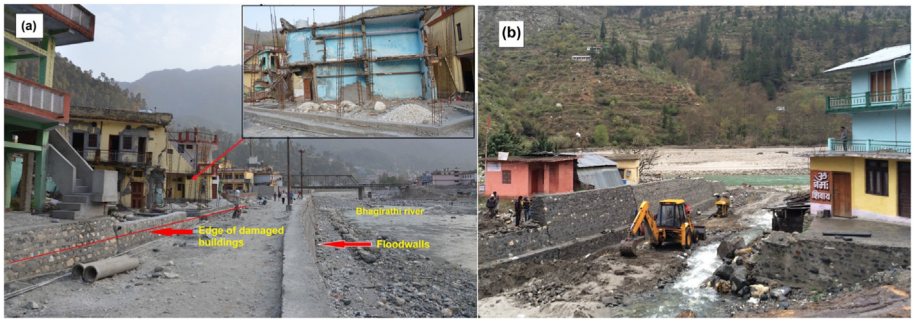

Fig. 5. Field photograps at (a) Tiloth, and (b) Dharali showing newly constructed floodwalls along the Bhagirathi river and its tributary. The reconstruction of damaged house in the same place after damage shown inset in figure (a).

inhabitant reconstructed buildings in the same places that are prone to floods. After getting a lesson from the deluge 2013, the state government is now constructing floodwalls and safeguards along the bank of Bhagirathi rivers and its tributaries in disaster prone area. But, most of the structures are built at banks close to water flow (Fig. 5) without taking any scientific study for flood extent and flood depth. Hence, the effectivity of floodwalls to restrain flood water is uncertain, as earlier researcher doubted in their study elsewhere [56,57].

6. Conclusion and recommendation

This study is focused to identify high flood level and to analyze the governance issues on land use policies related to flood disaster in Uttarakhand with particular reference to Bhagirathi river basin. Aided with flood modeling, this paper focused on investigating the gaps and implementation issues in policies that failed to control development activities balancing environmental sustainability. Overall, the study found anthropogenic influence to aggravate the calamity that could be minimized through adaptation and implementation of effective policies and plans.

This study showed that weak land use policies and implementation issues has caused the failure of governance to reduce and mitigate vulnerability to flood hazards. The state government had promoted development activities overlooking environmental health and ecology. Weak building regulations and hydropower policies were found most crucial for increasing the scale of the disaster in June 2013. Besides, lack of good governance regarding transparency, accountability, efficiency and coordination had failed to implement and update the existing policies; and indirectly exacerbated the disaster.

The state government should take effective steps in multi-institutional coordination for risk identification and assessments, land use planning, implementation of mitigation strategies, monitoring and evaluation of mitigation performance. The government is required to focus on the development of local mitigation plans and providing technical assistance to local governments. This study suggests few recommendations that could be incorporated into policy making to reduce flood vulnerability in Uttarakhand:

(i) Decentralization of power at horizontal and vertical level among multi-institutions for preparing planning and policies, controlling and implementing regulations, and regular updating of policies. Transparency in governance to implement regulations beyond political and economic benefits must be ensured.
(ii) Emendation of building bylaws incorporating safe distance for construction from riverside with a prior hydraulic study by experts is required. The construction and reconstruction for tourism should strictly follow the guidelines of UTDB [53]. The GoU required adopting new policies for tourism management and vehicle pressure control.
(iii) Revision of hydropower policy incorporating environmental impact assessment, environmental flow, lock gate operation etc. The policy must include mandatory installation of automated weather station and real-time flood forecasting system at every medium to large hydropower plants, clear direction on lock gate operation during peak flow. The government should strictly follow Dam safety bill (2005) of Government of India and regulate HEPs activities.
(iv) Immediate application Uttaranchal Disaster Mitigation, Management and Prevention Act (2005). Being a disaster prone sate, the government needs to pay attention in disaster preparedness accounting a local level emergency plan for rescue and relief operations. The policy framework must follow the guidelines of 'Sendai Framework for Disaster Risk Reduction 2015–2030' as proposed by United Nations.
(v) The government should prepare a strong rehabilitation accounting reconstruction damaged buildings through developing land bank at safer place. The government should be intended to prevent new constructions in hazardous areas in the first place, and relocation of existing structures before or after a disaster event.
(vi) Implementation of standard land use policy by defining land utilization zones along river bank in flood prone area, and unique policy for each Eco Sensitive Zone by incorporating local level plans.
(vii) Catchment Area Treatment (CAT) plan, afforestation and reforestation, proper management of mock disposal must be ensured by any industrial work project under the regular inspection of government officials.

The state government needs to promote and invest for insurance of life, health, property and wealth, agricultural land and other infrastructure through appropriate policy measures for the resilience of flood affected communities. The impact of deluge 2013 is still affecting socio-economic conditions of the local inhabitants. Therefore, the government needs for 'back-casting' to involve working backward from a targeted future to the present through adopting suitable policy measures and good governance.

Acknowledgements

The authors are thankful to Special Centre for Disaster Research (SCDR, JNU) and National Institute of Disaster Management (NIDM), Ministry of Home Affairs, Govt. of India, New Delhi for providing financial support for this project. NASA-METI, USGS, NCEP, USACE-HEC, Bing map, Google Earth and Census of India are highly acknowledged for providing freely available data and tools that used in this study. The anonymous reviewers are also acknowledged for their suggestions to improve the quality of the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2019.101090.

References

[1] E. Neumayer, F. Barthel, Normalizing economic loss from natural disasters: a global analysis, Glob. Environ. Chang. 21 (1) (2011) 13–24.

[2] S. Du, P. Shi, A.V. Rompaey, J. Wen, Quantifying the impact of impervious surface location on flood peak discharge in urban areas, Nat. Hazards 76 (2015) 1457–1471, https://doi.org/10.1007/s11069-014-1463-2.

[3] J. Li, P. Feng, F. Chen, Effects of land use change on flood characteristics in mountainous area of Daqinghe watershed, China, Nat. Hazards 70 (2014) 593–607, https://doi.org/10.1007/s11069-013-0830-8.

[4] S. Suriya, B.V. Mudgal, Impact of urbanization on flooding: the Thirusoolam sub watershed – a case study, J. Hydrol. 412–413 (2012) 210–219, https://doi.org/10.1016/j.jhydrol.2011.05.008.

[5] S. Detrembleur, F. Stilmant, B. Dewals, S. Erpicum, P. Archambeau, M. Pirotton, Impacts of climate change on future flood damage on the river Meuse, with a distributed uncertainty analysis, Nat. Hazards 77 (2015) 1533–1549, https://doi.org/10.1007/s11069-015-1661-6.

[6] U.S. De, G.P. Singh, D.M. Rase, Urban flooding in recent decades in four mega cities of India, Journal of Indian Geophysical Union 17 (2) (2013) 153–165.

[7] C. Ouellet, D. Saint-Laurent, F. Normand, Flood events and flood risk assessment in relation to climate and land-use changes: saint-François River, southern Québec, Canada, Hydrol. Sci. J. 57 (2) (2012) 313–325, https://doi.org/10.1080/02626667.2011.645475.

[8] A. Brath, A. Montanari, G. Moretti, Assessing the effect on flood frequency of land use change via hydrological simulation (with uncertainty), J. Hydrol. 324 (2006) 141–153, https://doi.org/10.1016/j.jhydrol.2005.10.001.

[9] D.P. Dobhal, A.K. Gupta, M. Mehta, D.D. Khandelwal, Kedarnath disaster: facts and plausible causes, Curr. Sci. 105 (2) (2013) 171–174.

[10] Gupta AK. Satendra, V.K. Naik, T.K. Saha Roy, A.K. Sharma, M. Dwivedi, Uttarakhand Disaster 2013, National Institute of Disaster Management, New Delhi, 2014, p. 184.

[11] P.P. Driessen, D.L. Hegger, M.H. Bakker, H.F. van Rijswick, Z.W. Kundzewicz, Toward more resilient flood risk governance, Ecol. Soc. 21 (4) (2016).

[12] A. Dube, R. Ashrit, A. Ashish, K. Sharma, G.R. Iyengar, E.N. Rajagopal, S. Basu, Forecasting the heavy rainfall during Himalayan flooding—June 2013, Weather and Climate Extremes 4 (2014) 22–34.

[13] J. Ahrens, P.M. Rudolph, The importance of governance in risk reduction and disaster management, J. Contingencies Crisis Manag. 14 (4) (2006) 207–220.

[14] K. Krieger, The limits and variety of risk-based governance: the case of flood management in Germany and England, Regulation & Governance 7 (2013) 236–257, https://doi.org/10.1111/rego.12009.

[15] S. Lavery, B. Donovan, Flood risk management in the Thames Estuary looking ahead 100 years, Philos. T. R. Soc. A 363 (2005) 1455–1474.

[16] J.D. Bakibinga-Ibembe, V.A. Said, N.W. Mungai, Environmental laws and policies related to periodic flooding and sedimentation in the Lake Victoria Basin (LVB) of East Africa, Afr. J. Environ. Sci. Technol. 5 (5) (2011) 367–380.

[17] P.R. Berke, W. Lyles, G. Smith, Impacts of federal and state hazard mitigation policies on local land use policy, J. Plann. Educ. Res. 34 (1) (2014) 60–76.

[18] J.R. Nolon, Disaster mitigation through land use strategies, Environ. Law Rep. 37 (2007) 10681–10691 ELR.

[19] E. Raju, P. Becker, Multi-organisational coordination for disaster recovery: the story of post-tsunami Tamil Nadu, India, Int J Disaster Risk Reduct 4 (2013) 82–91, https://doi.org/10.1016/j.ijdrr.2013.02.004.

[20] S. Deen, Pakistan 2010 floods. Policy gaps in disaster preparedness and response, Int J Disaster Risk Reduct 12 (2015) 341–349, https://doi.org/10.1016/j.ijdrr.2015.03.007.

[21] P. Kumar, D. Geneletti, How are climate change concerns addressed by spatial plans? An evaluation framework, and an application to Indian cities, Land Use Pol. 42 (2015) 210–226, https://doi.org/10.1016/j.landusepol.2014.07.016.

[22] A.C. Hurlimann, A.P. March, The role of spatial planning in adapting to climate change, Wiley Interdisciplinary Reviews: Climate Change, 2012.

[23] K. Urwin, A. Jordan, Does public policy support or undermine climate change adaptation? Exploring policy interplay across different scales of governance, Glob. Environ. Chang. 18 (2008) 180–191, https://doi.org/10.1016/j.gloenvcha.2007.08.002.

[24] A. Kazmierczak, G. Cavan, Surface water flooding risk to urban communities: analysis of vulnerability, hazard and exposure, Landsc. Urban Plann. 103 (2011) 185–197, https://doi.org/10.1016/j.landurbplan.2011.07.008.

[25] S.C. Moser, A.L. Luers, Managing climate risks in California: the need to engage resource managers for successful adaptation to change, Clim. Change 87 (2008) 309–322, https://doi.org/10.1007/s10584-007-9384-7.

[26] S. Ghosh, D. Raje, P.P. Mujumdar, Mahanadi streamflow: climate change impact assessment and adaptive strategies, Curr. Sci. 98 (8) (2010) 1084–1091.

[27] Ranger, et al., An assessment of the potential impact of climate change on flood risk in Mumbai, Clim. Change 104 (2011) 139–167, https://doi.org/10.1007/s10584-010-9979-2.

[28] A. Datta, India's ecocity? Environment, urbanisation, and mobility in the making of Lavasa, Environ. Plan. C Govern. Policy 30 (6) (2012) 982–996, https://doi.org/10.1068/c1205j.

[29] A. Follmann, Urban mega-projects for a 'world-class' riverfront - the interplay of informality, flexibility and exceptionality along the Yamuna in Delhi, India, Habitat Int. 45 (2015) 213–222 https://doi.org/10.1016/j.habitatint.2014.02.007.

[30] J.K. Panigrahi, S. Amirapu, An assessment of EIA system in India, Environ. Impact Assess. Rev. 35 (2012) 23–36 https://doi.org/10.1016/j.eiar.2012.01.005.

[31] K.H.V.D. Rao, V.V. Rao, V.K. Dadhwal, P.G. Diwakar, Kedarnath flash floods: a hydrological and hydraulic simulation study, Curr. Sci. 106 (4) (2014) 598–603.

[32] C.P. Kala, Deluge, disaster and development in Uttarakhand Himalayan region of India: challenges and lessons for disaster management, Int J Disaster Risk Reduct 8 (2014) 143–152 http ://dx.doi.org/10.1016/j.ijdrr.2014.03.0 02.

[33] N. Rana, S. Singh, Y.P. Sundriyal, N. Juyal, Recent and past floods in the Alaknanda valley: causes and consequences, Curr. Sci. 105 (9) (2013) 1209–1212.

[34] Asha, et al., Assessment of Cumulative Impacts of Hydroelectric Projects on Aquatic and Terrestrial Biodiversity in Alaknanda and Bhagirathi Basins, Uttarakhand, Wildlife Institute of India, Technical Report, 2012, p. 203.

[35] Expert Body Report, Assessment of Environmental Degradation and Impact of Hydroelectric Projects during the June 2013 Disaster in Uttarakhand, (2014) http://www.indiaenvironmentportal.org.in/files/file/environmental%20degradation%20&%20hydroelectric%20projects.pdf , Accessed date: 25 January 2016.

[36] I. White, J. Richards, Planning policy and flood risk: the translation of national guidance into local policy, Plann. Pract. Res. 22 (4) (2007) 513–534.

[37] R.S. Deshpande, M.J. Bhende, Land Resources and Policy in Karnataka, Institute for Social and Economic Change, Nagarbhavi, Bangalore, 2003 Working Paper 132.

[38] A. Kumar, Pushplata, Building regulations for hill towns of India, HBRC Journal 11 (2) (2015) 275–284 https://doi.org/10.1016/j.hbrcj.2014.06.006.

[39] J. Barbedo, M. Miguez, D.V. Horst, P. Carneiro, P. Amis, A. Ioris, Policy dimensions of land-use change in periurban floodplains: the case of Paraty, Ecol. Soc. 20 (1) (2015) 5 https://doi.org/10.5751/ES-07126-200105.

[40] K.S. Shrivastava, Maximum devastation occurred in areas of maximum forestland diversion. Down to Earth, http://www.downtoearth.org.in/content/maximum-devastation-occurred-areas-maximum-forestland-diversion, (2013) , Accessed date: 11 February 2016.

[41] Census of India, District Census handbook: Uttarakhand, http://www.censusindia.gov.in/2011census/dchb/DCHB.html, (2011).

[42] E.P. Evans, D.M. Ramsbottom, J.M. Wicks, J.C. Packman, E.C. Penning-Rowsell, Catchment flood management plans and the modelling and decision support framework, Proceedings of ICE (2002) 43–48 Paper 12782.

[43] S.L. Neitsch, J.G. Arnold, J.R. Kiniry, J.R. Williams, Soil and Water Assessment Tool Theoretical Documentation. Version 2009. Grassland, Soil, and Water Research Laboratory, Agriculture Research Service, Texas A&M University System, 2011.

[44] W.W. Immerzeel, A. Gaur, S.J. Zwart, Integrating remote sensing and a process-based hydrological model to evaluate water use and productivity in a south Indian catchment, Agric. Water Manag. 95 (2008) 11–24.

[45] E.C. Carson, Hydrologic modeling of flood conveyance and impacts of historic overbank sedimentation on West Fork Black's Fork, Uinta Mountains, northeastern Utah, USA, Geomorphology 75 (2006) 368–383, https://doi.org/10.1016/j.geomorph.2005.07.022.

[46] J.G. Arnold, et al., SWAT: model use, calibration, and validation, ASABE 55 (4) (2012) 1491–1508.

[47] A.K. Srivastava, P. Guhathakurta, Climate Diagnostics Bulletin of India June 2013, near real-time analysis. Issue number 208. India meteorological department, MoES, Earth system science organisation, govt. Of India, www.imdpune.gov.in/research/ncc/climatebulletin/cdbi_Jun_2013.pdf, (2013).

[48] IMD, A Preliminary Report on Heavy Rainfall over Uttarakhand during 16–18 June 2013, India Meteorological Department, Ministry of Earth Sciences, 2013 July, http://imd.gov.in/doc/uttrakhand_report_04_09_2013.pdf.

[49] JRDNA Report, India- Uttarakhand Disaster, June 2013. Joint Rapid Damage and Needs Assessment Report, August 2013. Jointly Prepared by Govt. Of Uttarakhand, the World Bank and the Asian Development Bank, 2013.

[50] SANDRP, UttarakhandDisaster: MoEF Should Suspend Clearances to Hydropower Projects and Institute Enquiry in the Role of HEPs, (2013) https://sandrp.wordpress.com/2013/07/20/uttarakhanddisastermoefshouldsuspectclearancestohydropowerprojectsandinstituteenquiryintherole-of-heps/ , Accessed date: 27 January 2016.

[51] J. Mazoomdaar, A. Langer, Uttarakhand: a model of disaster. Tehelka, http://www.tehelka.com/uttarakhand-a-model-of-disaster/, (2013) , Accessed date: 25 February 2016.

[52] Forest Department, Government of Uttarakhand (2014) (http://forest.uk.gov.in/files/MPR_AUGST/Summary_Notification.pdf) [accessed on 17.03.2016].

[53] UTDB, Infrastructure Development Guidelines: Developing New Infrastructure under Tourism Sector, Including Any Rehabilitated and Reconstructed Tourism Infrastructure, Uttarakhand Tourism Development Board, 2015 UTDB-IDG-01.

[54] B. Sinha, Uttarakhand rejects govt report on 2013 floods, Hindustan Times (Feb 17, 2015) https://www.hindustantimes.com/india/uttarakhand-rejects-govt-report-on-2013-floods/story-qUbZMPkxxam8JcmKIYmzuK.html, (2015) , Accessed date: 28 November 2017accessed on.

[55] P. Samuels, F. Klijn, J. Dijkman, An analysis of the current practice of policies on river flood risk management in different countries, Irrigat. Drain. 55 (2006) S141–S150.

[56] M. Spreafico, Flash floods in mountain areas, Proceedings of the Fifth FRIEND World Conference Held at Havana, Cuba, November 2006, vol. 308, IAHS Publ, 2006, pp. 232–238.

[57] J. Yin, D. Yu, Z. Yin, J. Wang, S. Xu, Modelling the anthropogenic impacts on fluvial flood risks in a coastal mega-city: a scenario-based case study in Shanghai, China, Landsc. Urban Plann. 136 (2015) 144–155, https://doi.org/10.1016/j.landurbplan.

2014.12.009.

[58] Z.W. Kundzewicz, S. Kanae, S.I. Seneviratne, J. Handmer, N. Nicholls, P. Peduzzi, R. Mechler, L.M. Bouwer, N. Arnell, K. Mach, R. Muir-Wood, Flood risk and climate change: global and regional perspectives, Hydrolog. Sci. J. 59 (1) (2014) 1–28.

[59] M. Hurlbert, J. Gupta, Adaptive governance, uncertainty, and risk: policy framing and responses to climate change, drought, and flood, Risk Anal. 36 (2) (2016) 339–356.

[60] S. Nandargi, A. Gaur, S.S. Mulye, Hydrological analysis of extreme rainfall events and severe rainstorms over Uttarakhand, India, Hydrolog. Sci. J. 61 (12) (2016) 2145–2163.

[61] A. Chevuturi, A.P. Dimri, Investigation of Uttarakhand (India) disaster-2013 using weather research and forecasting model, Nat. Hazards 82 (3) (2016) 1703–1726.